Investigation of Factors Promoting Competitive Candidates for Entry-level Bioengineering Positions

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I am a MEng student in Bioengineering, with a BS, Bioengineering, both from University of Illinois, Urbana-Champaign. I am interested in biomechanics and how curriculum structure affects education outcomes.

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Introduction

In this works-in-progress paper, we describe the need for standardization of curriculums in biomedical (BME) and bioengineering (BIOE) programs. The Engineers' Council for Professional Development (ECPD), founded in 1932 and later renamed the Accreditation Board for Engineering and Technology in 1980, began reviewing the first engineering degree programs in 1936 [1]. By 1947, ECPD had accredited 580 undergraduate engineering programs. However, biomedical/bioengineering programs did not receive accreditation until the 1970s, and even by 2000, only twenty-six programs were ABET accredited. However, biomedical/bioengineering programs have experienced rapid growth (Figure 1) since 2000, and there are now 115 ABET accredited programs [1].

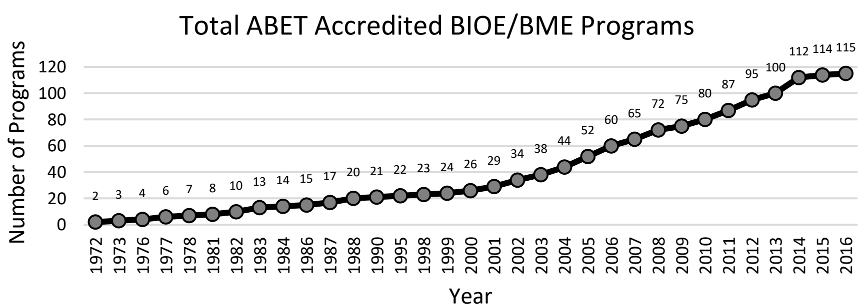

Figure 1. Since around 2000, the number of ABET approved undergraduate biomedical/bioengineering programs has rapidly increased (last updated on ABET site October 2017) [1].

Despite the rapid growth in ABET accredited biomedical/bioengineering programs, there is still a lack of consensus on the core curriculum and key foundational skills of a biomedical or bioengineer. Conversely, well-established engineering fields (e.g. electrical engineering) support curriculums that cover the same foundational core concepts, regardless of offering institution.

Identifying key foundational areas and standardizing them among multiple institutions' curriculums ensures students have been exposed to consistent concepts and may be evaluated with standardized exams such as the Fundamentals of Engineering Exam (FE). In addition, industry recruiters are better able to evaluate candidates from engineering fields with standardized core engineering competencies. Because BME and BIOE programs have not established a core set of competencies across curriculums, industry recruiters with limited knowledge of specific biomedical/bioengineering programs may not be confident in hiring students from unfamiliar programs. For example, some programs focus on biological aspects (e.g., tissue engineering) while other programs focus on applying traditional engineering to living systems (e.g. medical device development) [2]. Without standardized core competencies, it may be unclear to an industry recruiter what skills each biomedical/bioengineer has, which may discourage the company from recruiting through biomedical/bioengineering programs. A pervasive goal in higher education is to help students secure their next destination; however, the lack of standardization previously acknowledged by Linsenmeier [3-5] continues to be a barrier to opening doors for biomedical/bioengineering graduates.

Although there is a lack of standardization, there may be a natural convergence of key concepts. The similarities and differences across accredited (n=40 of 43 accredited at the time) and soon to be accredited programs (n=31) was reviewed by VaNTH (Vanderbilt-Northwestern-Texas-Harvard/MIT) and the ERC (Engineering Research Center) in 2004; a smaller version of this study (n=16) was repeated in 2013 [2]. Results from Gatchell and Linsenmeier's study [2], suggest a set of core competencies exists. Within this core are principles in mechanics, physiology, and design with biology, circuit analysis, computing, statistics, materials, and instrumentation; transport and signals and systems were also close to the marker for core. However, recruiter hesitance to hire biomedical/bioengineers for standard engineering roles remains [5].

Therefore, as a field we should focus on developing a standardization amongst curriculums leading us to core competencies in our biomedical/bioengineering programs. Throughout this development, a focus on industry-needs may prove beneficial, as we have seen an ever-growing call from industry to train our students in regulatory affairs and quality engineering [6]. These topics are beyond the immediate scope of this paper, but are topics of interest for future studies. In the interim, it would be beneficial for the Biomedical Engineering Society (BMES) to review the requirements for biomedical/bioengineering undergraduate programs' ABET accreditation.

Motivation for study

We are seeking different ways to incorporate the aforementioned core competencies as we renovate our bioengineering program's curriculum. In addition, we are seeking to examine if a specialization in a specific bioengineering focus is beneficial for students pursuing industry. The purpose of our overall study is four-fold, yet in this paper, we focused on specific tasks to allow us to create the foundation for implementing the overall study.

Overall study:

1. To determine if a correlation exists between track choice and career choice,
2. To determine if a correlation exists between track choice and obtaining an internship/co-op,
3. To determine if a correlation exists between undergraduate research experience and entry-level BME/BIOE industry jobs, and
4. To determine industry perceptions of bioengineering student competencies.

Objectives of this works-in-progress study:

1. Review the literature on BME/BIOE curriculums
2. Review departmental data as a pilot of the planned study
3. Develop instruments to acquire data needed for our study. Specifically, develop a survey tool to acquire student and alumni data.

Insights gained from this study will be used to develop advising tools and provide further insight into the skills industry employers are seeking from bioengineering majors. Herein, we present an overview of the bioengineering tracks, methods used, and preliminary results from the class of 2017.

Overview of bioengineering tracks

Our institution's bioengineering program consists of the curriculum requirements and core competencies previously mentioned, less a required mechanics or materials engineering course. In order to provide students with a focus area in their field, we offer five technical tracks: cell and tissue engineering, therapeutics engineering, biomechanics, computational and systems biology, and imaging and sensing. Each student must declare their track by the end of their sophomore year, and complete 15 credit hours selected from a variety of coursework offered for the selected track.

All track course options are in an engineering discipline, and students must complete fifteen credit hours in their selected track. Of the five track options offered, two tracks require three core courses (biomechanics and imaging and sensing tracks), while the remaining tracks allow students to select approximately five courses, or fifteen hours, from a variety of options. Many of the track courses are either cross-listed with the bioengineering department, owned by the bioengineering department, or are in allied departments. For example, most of the biomechanics courses are offered through by the Mechanical Science and Engineering Department. In addition, many of the therapeutics and some cell and tissue engineering track course options are offered through the Material Science and Engineering Department. The Computer Science Department offers several of our track options for the computational and sensing track, and some imaging and sensing track options are housed in the Electrical and Computer Engineering Department. Table 1 provides a list of courses that students may take for each track; courses noted with an asterisk are required courses in the track.

Figure 2 indicates that therapeutics engineering and cell and tissue engineering are consistently popular tracks across cohorts. For spring 2018, of the 253 total students in the program, sixty-six have declared therapeutics engineering, and sixty-two have declared cell and tissue engineering; some sophomores still need to declare a track. While we only have observational anecdotal data at this point, we can see certain tracks seem to be associated with specific career goals (Table 2). For example, the majority of students (*%)* in the cell and tissue engineering track pursue medical school.

Table 1. Sample of courses available in each track. Some courses are offered in multiple tracks; courses noted with an asterisk are required courses in the track.

Biomechanics	**Cell and Tissue Engineering**	**Therapeutics Engineering**	**Computational and Systems Biology**	**Imaging and Sensing**
Statics*	Techniques in Biomolecular Engineering	Techniques in Biomolecular Engineering	Data Structures	Analog Signal Processing *
Dynamics*	Biochemical Engineering	Cancer Nanotechnology	Introduction to Data Mining	Introduction to Electromagnetic Fields
Solid Mechanics*	Design and Use of Biomaterials	Design and Use of Biomaterials	Applied Statistical Methods	Digital Signal Processing
Cellular Biomechanics	Biomaterials and Nanomedicine	Biomaterials and Nanomedicine	Deterministic Models in Optimization	Digital Signal Processing Lab
Whole Body Musculoskeletal Biomechanics	Biomaterials Lab	Biomaterials Lab	Stochastic Processes and Applications	Biomedical Imaging
Musculoskeletal Tissue Mechanics	Biofabrication Lab	Biofabrication Lab	Introduction to Optimization	Optical Imaging
Continuum Mechanics	Introduction to Synthetic Biology	Introduction to Synthetic Biology	Introduction to Synthetic Biology	Biophotonics
Engineering Materials	Biosensors	Biomolecular Materials Science	User Interface Design	Biosensors
Computer Aided Product Realization	Systems Bioengineering	Systems Bioengineering	Systems Bioengineering	MEMS-NEMS Theory and Fabrication
	Industrial Quality Control	Polymer Science and Engineering	Artificial Intelligence	Fundamentals of Engineering Acoustics
	Stem Cell Engineering	Biological Nanoengineering		Magnetic Resonance Imaging
	Experimental Genetic Engineering	Imaging and Therapeutic Agents		Imaging and Therapeutics Agents
		Preclinical Molecular Imaging		Preclinical Molecular Imaging
		Synthesis of Materials		Fields and Waves I*

Methods

Prior to Fall 2017, students chose a track and completed the track coursework; the students' track and coursework were then recorded by the college office during the degree certification period. This process did not allow us to monitor students' track selection throughout their college career or easily identify how many students were in each track in a given semester. Effective Fall 2017, in partnership with our engineering informational technology department, we created a reporting category where the advising team could record each student's track selection by semester. This additional reporting technology also allows us to monitor track changes through a student's academic career. To gain further insight into our students' track course progress, career, and graduate school goals, we developed a mandatory pre-advising questionnaire asking the students to identify their (1) current track, (2) courses taken towards current track, (3) career interests and post-graduation plans, and (4) student groups or other campus activities. Bioengineering requires freshmen-juniors to meet for advising each semester before they can register for classes; seniors are provided a copy of their graduation audit (courses remaining to graduate).

The advising questionnaire and additional reporting technology allowed us to collect data from our current students. To obtain data from alumni, we developed a separate survey tool. The data from the alumni survey (an in-works study) is beyond the scope of this paper; however, the data will allow us to create a more complete picture in future studies examining our previously noted research questions. Once we have fully developed and implemented all aspects of our study, we plan to solicit replication of our study from other BME/BIOE programs to increase the sample size and strength of any forthcoming recommendations.

Preliminary Results

Objective 1

A literature review of BME/BIOE curriculums is covered in the introduction of this paper. Linsenmeier et al., in previous work [3-5], provided thorough overviews of how the curriculum of BME/BIOE is beginning to naturally converge on a set of topics. Yet, as an accredited field, we have not established the standard core competencies that all BME/BIOE programs must cover.

Objective 2

Figure 2 displays the student track selection for each freshman admit year; most students are admitted to the bioengineering program and enter in their freshmen year. However, each year, there are a few students transferring into bioengineering during fall of sophomore year. Students are not required to select a track until the end of their sophomore year; therefore, data from admit years fall 2016 and fall 2017 is preliminary. Although students are required to choose a track by the end of sophomore year, juniors and seniors are permitted to change tracks. If students elect to change their track, they still must complete fifteen engineering credit hours in their newly selected track. To provide further insight into the bioengineering tracks, we offered a pilot course to freshmen in spring 2017 that focused on applying each of the five tracks to investigate different medical challenges.

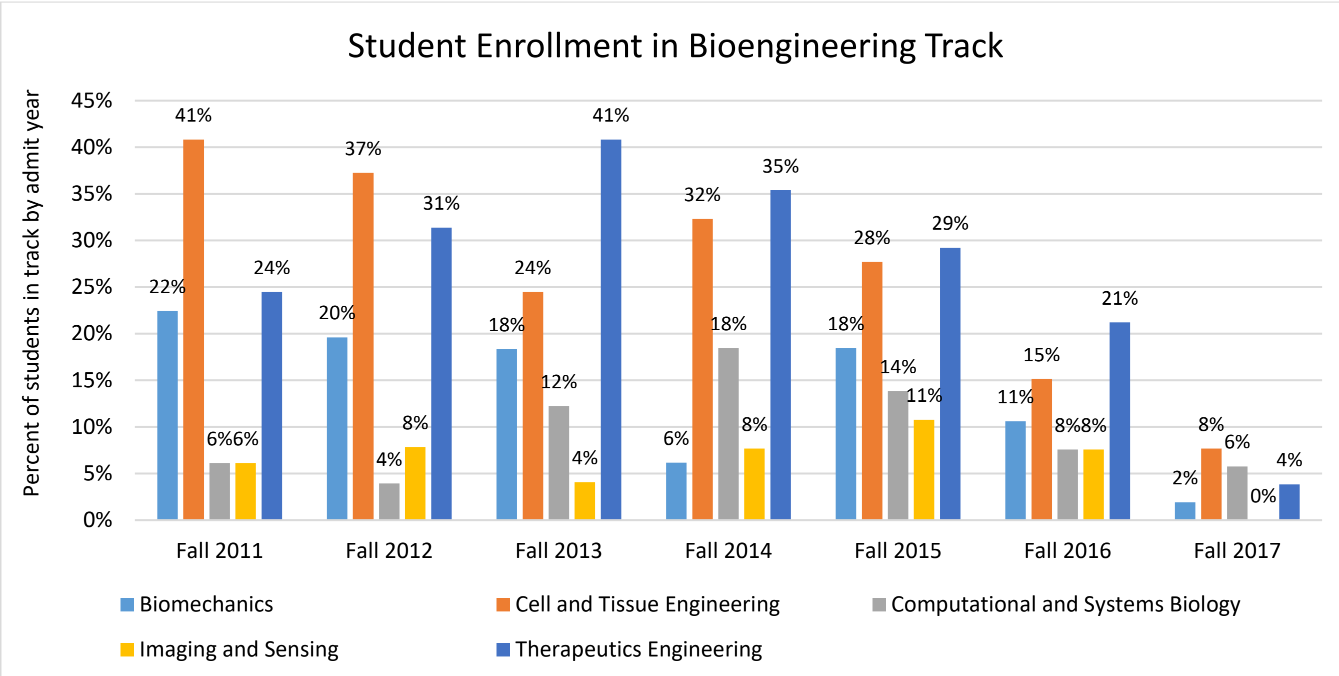

Figure 2. Enrollment in bioengineering track by student admit year (cohort). Students select tracks at the end of their sophomore year; preliminary data is reported for fall 2016 and fall 2017 as students are not required to choose a track until the end of their sophomore year (Data retrieved in February 2018).

Table 2 displays track and career information from the graduating class of 2017. Career information was obtained from a survey on career plans that the students completed in their senior design course (in late Spring 2017); track information was obtained from information in degree certification documents. For the Fall 2013 admits (n=49), most of whom graduated in May 2017, the most popular track was therapeutics engineering with 41% of the cohort completing this track (Figure 2). Of the fifty-five students graduating in 2017, forty-one responded with career placement information (not all career survey respondents graduated in 2017), and 51% of those graduating and responding selected industry as a career path (Table 2). Of those selecting industry (n=21), the biomechanics track and the therapeutics engineering track were well represented with 50% (n=5) of the biomechanics respondents choosing industry and 76% (n=13) of the therapeutics respondents choosing industry. From the placement information, 51% of the reporting seniors chose industry, 27% chose graduate school, and 22% chose medical school. Eighty percent of the students in the computational and systems biology track pursued graduate school, and 50% of the students in cell and tissue engineering track pursued medical school, with an additional 25% of the cell and tissue engineering track pursuing graduate school.

The outlier is the imaging and sensing track in that only one student pursued this track and reported a career focus; therefore, while a trend may be seen in other tracks, this track trend cannot be generalized.

Table 2. Career placement and bioengineering track selection for the graduating class of 2017 (n=41 self-reported responses). For imaging and sensing, only one student pursued the track and reported a career focus so this data point is not reliable for a trend.

Count of Career plan	Column Labels			
Row Labels	Graduate School	Industry	Medical School	Grand Total
Biomechanics	30.00%	50.00%	20.00%	100.00%
Cell & Tissue Engineering	25.00%	25.00%	50.00%	100.00%
Computational & Systems Biology	80.00%	20.00%	0.00%	100.00%
Imaging & Sensing	0.00%	0.00%	100.00%	100.00%
Therapeutics	11.76%	76.47%	11.76%	100.00%
Grand Total	26.83%	51.22%	21.95%	100.00%

Objective 3

We have implemented resources to collect data on current students and will be collecting alumni data to provide a more complete overview. We developed a separate survey tool (Table 3) to collect data on (1) bioengineering track, (2) first destination placement, (3) career aspirations, (4) involvement on campus, and (5) other information potentially influential to career. We are seeking an Institutional Review Board approval for this survey and are working with our Development Office to distribute the survey; departments are not permitted to contact alumni directly at our institution.

Discussion and Future Work

Preliminary trend data suggest there may be a correlation between track choice and career. This is interesting as all students take the same core bioengineering courses and are only separated by the fifteen credit hours of track electives, where some track electives are options on multiple tracks. Further study is required to determine if this correlation exists, in addition to if a correlation exists among track choice and internship/co-op placement, and if a correlation exists between undergraduate research and industry positions. Based on the preliminary data, specific tracks may be stronger associated with industry careers. Our final purpose of this overall study is to gain insight on industry perceptions of bioengineering student competencies, including if different tracks have different competencies that better prepare students for industry.

More data review between students/alumni career focus and track choice is needed (survey in Table 3) to distill if a true relationship exists. Moderating variables that may influence students' decision to pursue industry careers may include extracurricular activities completed by the student, personal connections to industry personnel, training in soft-skill development, or completion of entrepreneurial projects [7].

From an advising standpoint, additional insight into correlations between tracks and next destinations (graduate school, medical school, industry opportunities) will provide a starting point for further discussion on career paths for students. For future studies, we will examine alumni data and obtain qualitative data from industry professionals regarding their perceptions of the competencies obtained through a bioengineering curriculum and the different track areas.

References

1. ABET: Search for Accredited Programs (February 4, 2018) Available: http://www.abet.org
2. D. W. Gatchell and R. A. Linsenmeier. “Similarities and Differences in Undergraduate Biomedical Engineering Curricula in the United States,” in American Society of Engineering Education Annual Conference, Indianapolis, IN 2014
3. R. A. Linsenmeier, T. R. Harris and S. A. Olds, "The VaNTH Bioengineering Curriculum Project," Proceedings of the Second Joint 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society/Engineering in Medicine and Biology, 2002, pp. 2644-2645 vol.3. doi: 10.1109/IEMBS.2002.1053470
4. T. Harris, D. Gatchell, and R. Linsenmeier. “Biomedical Engineering Key Content Survey – The 1st Step In A Delphi Study To Determine The Core Undergraduate BME Curriculum” Paper presented at 2004 Annual Conference, Salt Lake City, Utah. https://peer.asee.org/13365
5. R. A. Linsenmeier, "What makes a biomedical engineer?," in IEEE Engineering in Medicine and Biology Magazine, vol. 22, no. 4, pp. 32-38, July-Aug. 2003
6. Lisa Waples (organizer). “BMES Industry Panel and Workshop” in *Biomedical Engineering Society Annual Meeting*, Phoenix, Arizona 2017
7. R. W. Lent, et al. "Career choice barriers, supports, and coping strategies: College students' experiences." *Journal of Vocational Behavior,* vol. 60 issue 1, pp. 61-72, 2002 https://doi.org/10.1006/jvbe.2001.1814

Table 3. Survey developed to collect information from alumni on bioengineering track and career aspirations

Career and track survey

1. Name

[ ]

2. Please Select your undergraduate track:

- ○ Biomechanics
- ○ Tissue Engineering
- ○ Therapeutics
- ○ Imaging & Sensing
- ○ Computational and Systems Biology

Other, list name of track

[ ]

3. Year Graduated

[ ]

4. Are you a legacy student (Parent, Grandparent, Sibling attended University of Illinois, Urbana-Champaign)

- ○ Yes
- ○ No
- ○ Unsure

5. Highest level of education of Parent/Guardian #1:

- ○ GED
- ○ Highschool Diploma
- ○ Trade School/Certificate Program
- ○ Associate's Degree
- ○ Bachelor's Degree
- ○ Other/Unknown (please specify)
- ○ Master's Degree
- ○ Doctoral (PhD)
- ○ Medical Degree (MD/DO)
- ○ Law Degree (JD)

[ ]

6. Highest level of education of Parent/Guardian #2:

- ◯ GED
- ◯ Highschool Diploma
- ◯ Trade School/Certificate Program
- ◯ Associate's Degree
- ◯ Bachelor's Degree
- ◯ Other /Unknown(please specify)
- ◯ Master's Degree
- ◯ Doctoral (PhD)
- ◯ Medical Degree (MD/DO)
- ◯ Law Degree (JD)

7. Does an immediate family member have a medical or engineering degree?

- ◯ No
- ◯ Yes (please detail relationship of family member and degree earned)

8. Were you a transfer student?

- ◯ Yes
- ◯ No

9. What college did you transfer from? List the name of college and City, State

10. Were you part of the Engineering Pathways Program?

- ◯ Yes
- ◯ No
- ◯ Unsure

11. Did you use Engineering Career Services for career advising while enrolled?

- ◯ No
- ◯ Yes, please indicate frequency per semester

12. Did you use The Career Center (all majors, on Wright St.) for career advising while enrolled?

- ◯ No
- ◯ Yes, please indicate frequency per semester

13. Did you participate in any of these professional development activities while in college?

- ☐ Internship
- ☐ Co-op
- ☐ Research experience
- ☐ Study abroad
- ☐ Other (please specify)

14. What did you pursue after graduation?

- ◯ Medical school
- ◯ Law school
- ◯ PhD
- ◯ Masters of Science
- ◯ Masters of Engineering
- ◯ Peace Corps
- ◯ Industry
- ◯ Other (please specify)

15. What subject did you study after you completed your undergraduate degree?

- Biomedical Engineering/Bioengineering
- Chemistry/Chemical Engineering
- Electrical Engineering
- Computer Science
- Mechanical Engineering
- Materials Science
- Biology
- Other (please specify)

16. When did you start your first job? (month,year)

17. When you started your first position, what industry did you work in?

- [ ] Medical Devices
- [ ] Pharmaceuticals
- [ ] Consulting
- [ ] Startup
- [ ] Other (please specify)

18. Please state your starting salary from your first full-time job.

19. Please state your signing bonus from your first full-time job (if none, please put 0).

20. What company were you first employed with? (Please include location)

21. Which describes your current occupation?

- Pursuing Higher Education (medicine, law, PhD, master's)
- Working in consulting
- Working in medical devices
- Working in a startup
- Working in pharmaceuticals
- Other (please specify)

22. If you are in an industry position, what company do you currently work for? (please include location)

23. Please state your current salary.

24. For the following, please indicate the best choice that reflects your feelings.

	Fully Agree	Somewhat Agree	Neutral (cannot say, don't have a strong feeling either way)	Somewhat Disagree	Fully Disagree
When selecting my track, I had an understanding of the career paths associated with my track.	◯	◯	◯	◯	◯
Upon graduation, I had an understanding of the career paths associated with my track.	◯	◯	◯	◯	◯
I thoroughly researched my track choices before I selected one.	◯	◯	◯	◯	◯
My track choice influenced my career choice.	◯	◯	◯	◯	◯
My track choice prepared me for my career.	◯	◯	◯	◯	◯
Informing recruiters of the content of my chosen track got me an interview.	◯	◯	◯	◯	◯
I currently work in a field related to my track.	◯	◯	◯	◯	◯
I currently use skills I gained from my track.	◯	◯	◯	◯	◯
I currently use skills I gained from the general bioengineering curriculum.	◯	◯	◯	◯	◯
I currently use none of the content (systems, fluids, mechanics, etc...) I learned in undergrad.	◯	◯	◯	◯	◯

25. Please leave comments about any of the above questions, we appreciate all insights.

26. Additional space for comments.